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Design, Operation, and Maintenance of the Automated Rotation Control System for the 2.5-Meter Observa-Dome

Judson LaMoure Shattuck, III
Vincent A Schmidt, PhD
Pawlos Campbell
Jacob Kern

Warfighter Interface Division
Battlespace Visualization Branch

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AIR FORCE RESEARCH LABORATORY
711TH HUMAN PERFORMANCE WING,
HUMAN EFFECTIVENESS DIRECTORATE,
WRIGHT-PATTERSON AIR FORCE BASE, OH 45433
AIR FORCE MATERIEL COMMAND
UNITED STATES AIR FORCE

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Date: 2013.03.29 10:01:57 -04'00'

JUDSON L SHATTUCK, III
Battlespace Visualization Branch

CRAIG.JEFFREY.L.1230201885
Digitally signed by CRAIG.JEFFREY.L.1230201885
DN: c=US, o=U.S. Government, ou=DoD, ou=PKI, ou=USAF, cn=CRAIG.JEFFREY.L.1230201885
Date: 2013.03.29 11:04:19 -04'00'

JEFFREY L CRAIG
Chief, Battlespace Visualization Branch
Decision Making Division

FREEMAN.GEORGE.R.1019635976
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DN: c=US, o=U.S. Government, ou=DoD, ou=PKI, ou=USAF, cn=FREEMAN.GEORGE.R.1019635976
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G. RICHARD FREEMAN
Chief, Warfighter Interface Division
Human Effectiveness Directorate
711 Human Performance Wing

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Judson LaMoure Shattuck, III
Vincent A Schmidt, PhD
Pawlos Campbell
Jacob Kern

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14. ABSTRACT
The purpose of this document is to highlight the design concept, operation, and maintenance of the automated dome rotation system used to control the 2.5-meter Observa-Dome.

15. SUBJECT TERMS
Control System, Observa-Dome, Dome Rotation, Automated Rotation.

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1.0 SUMMARY

The purpose of this document is to provide documentation for the design, operation, and maintenance of the Automated Rotation Control System for the 2.5-meter Observa-Dome, the observatory dome for the RHCV 17.5" telescope.

Prior to automation, the Observa-Dome and its shutter doors were rotated clockwise or counter clockwise with a hand operated drum switch connected to an AC gearhead. This configuration was not capable of being computer-controlled, and required the operator to either stand on the hydraulic platform (with the telescope) or stand on the floor beneath the platform. If it was operated while standing on the platform, the operator's body movement could cause the platform to sway, causing the telescope to shift and degrade data collection images. Standing underneath the platform eliminated possibility of operator-induced telescope vibration however, the view of the Observa-Dome shutter door was occluded.

The only reasonable solution was to automate the rotation of the Observa-Dome and synchronize the position of the shutters doors to the direction the telescope was pointing.

2.0 BACKGROUND

The Battlespace Visualization Branch requires a diverse collection of ground-based satellite images for research involving space situational awareness (SSA) and visualization. The objective of this research is to develop and demonstrate a native (in-house) capability to directly collect, process, analyze, and display ground-based images of satellites and space phenomena. These data will be utilized as inputs into branch SSA and visualization research activities. The research involves the selection and installation of an appropriate collection of imaging hardware, software, and computational components that will make up a research image collection and processing testbed.

In addition to providing timely and applicable research data, the Battlespace Visualization Branch will have improved ability to demonstrate the nature of the research cycle, from initial data collection, through processing and analysis, and into the SSA and visualization research products.

3.0 SPECIFICATION CONSIDERATIONS

The existing AC gearhead specifications are listed in Table 1.

Table 1. Existing gearhead specifications

¼ HP
50 ft.lbs Torque (67Nm)
12 RPM
Ratio of 144:1.

Atop the AC gearhead was mounted a 10” diameter rotational tire which was mounted so it was in constant contact with the 90” diameter inner ring of the Observa-Dome. Thus there was 9:1 ratio between the Observa-Dome and the rotational tire. At full speed, the Observa-Dome rotated 360° in 50 seconds, rotate approximately 7°/second, while the rotational tire rotated 3600° (10 full rotations).

The minimum requirements for the automated system are:

- Meet or exceed the maximum slew rate of the PlaneWave telescope, 7°/second utilizing the original 10” diameter rotational tire specified by Observa-Dome.
- Rotate clockwise and counterclockwise
- Have sufficient output torque to overcome Observa-Dome frictional forces for all temperatures normal for the Dayton, OH area. Since the original gearhead system was specified by Observa-Dome Laboratories, Inc. and has functioned properly the past 25 years, the replacement motor must meet or exceed
  - 50 ft.lb x (1.35582) = 67Nm
- Capable of being operated synchronously or asynchronously with the PlaneWave telescope.

4.0 SERVOMOTOR AND CONTROLLER SPECIFICATION

The automation equipment is manufactured by Kollmorgen Corporation and was selected because, as an industry leader in motion control, they offer and support servomotors, gearheads, encoders, interface cables, controllers and support software as matched equipment. The remaining in-house design work focused on external circuitry, electrical fusing and shutoffs, and safety guards which are detailed in Section 5, Motor and Controller External Circuitry. Table 2 briefly describes the major components of the replacement dome control system. Table 3 shows the performance specification of selected components compared to minimum requirements. Table 4 is a list of relevant documentation published by Kollmorgen Corporation used in the selection, design, operation, and maintenance of the Automated Rotation Control System for the 2.5-meter Observa-Dome.

Table 2. Replacement gearhead and controller specifications

Controller	AKD-P00306-NAAN-0000	Position indexer (motion tasking) AKD series brushless servo drive, rated 3 A continuous 120/240 VAC 1 phase or 3 phase, with analog command.
Servomotor	AKM31E-ACCNC-00	AKM series brushless servomotor with international standard mount, smooth shaft, motor-mounted rotatable 90° dual interconnect connectors, w/o brake, smart feedback device, 1.2Nm Constant Torque, 2500RPM
Gearhead	XT-080-100-0	Micron XT Gearhead 100:1, 88% efficient
Encoder	HC625500063DT	Model: Size 25 Enclosed, with Shaft Seal, PPR: 5000, Mechanical: 2.50"" Servo Mount/3 Hole, 1.88"" BC Face Mount, 3/8"" Shaft, Output: 10 Pin Connector or Cable (Differential, with Index, Format A, Table 1), Electrical: 5-26V in, 5V Line Driver out (with extend. temp range), Termination: 15' Watertight, End, Options: None
Motor Power Cable	VP-507BEAN-12	12 Meter cable
Motor Feedback Cable	VF-DA0474N-12	12 Meter cable

Table 3. Performance specification of selected components compared to minimum requirements

Minimum Requirement	AKD Specification	Performance Status
The original 10” diameter rotational wheel must be capable of rotating at least 12 RPM. (7°/second slew rate).	(2500 RPM Servomotor) / (100:1 Gearhead reduction) = 25 RPM (16°/second slew rate)	Exceed spec by 13 RPM (9°/second slew rate faster than required)
Rotate clockwise and counter clockwise	Rotate clockwise and counter clockwise	Meet spec
Output torque equal 67.8 Nm	(1.2 Nm constant torque) x (100:1 Gearhead reduction) x (.88 efficiency) = 105.6 Nm	Exceed spec by 37.8 Nm

Table 4. List of relevant documentation used in the selection, design, operation and maintenance of the Automated Rotation Control System for the 2.5-Meter Observa-Dome

Name of Manual	Manufacturer	Part Number
AKD Installation Manual	Kollmorgen Corporation	903-200003-00
Experience Scalable Programmability	Kollmorgen Corporation	KM-B-00013-RevB-EN
AKD User Guide	Kollmorgen Corporation	903-200006-00
AKD Servomotor Selection Guide	Kollmorgen Corporation	KM_SG_00077RevA_EN
AKM Power Cable (VP-507BEAN)	Danaher Motion	20-55008
AKM Feedback Cable (VF-DA0474N)	Danaher Motion	20-55006
AKD TRUE Planetary Gearheads	200712-02 TPS 3K	200712-02 TPS 3K
Series HC625500060DT Encoder Technical Bulletin	Dynapar	702382-0001

5.0 SERVOMOTOR AND CONTROLLER EXTERNAL CIRCUITRY

The external circuitry for the automated rotation control system is a user specific modification of the recommended external circuitry by Kollmorgen Corporation. Several important notes concerning the user specific modification are listed in Table 5.

Table 5. User specific modifications to the recommended external circuitry by Kollmorgen

AKD-x00306 Connector	Modification Description
X10	No modification, used VF-DA0474N-12 feedback cable
X2	No modification, used VP-507BEAN-12 power cable
X3 (1-3)	Brake Resistor not necessary, unused
X3 (4,5)	Filter and shielding not necessary, unused
X3 (6)	European application, unused
X3 (3)	STO single pull single throw switch is for European application, unused
X7 (1-10)	Unused
X8 (1,2)	Used to trip emergency Shut-Off if internal fault exists
X8 (3,5,6)	Unused
X8 (7)	Pulled to GND
X8 (8-10)	Unused
X5	Unused
X6	Unused
X12	Unused
X13	Unused
X9	See Table 9
X11	Unused

Several additions to the recommended external circuitry by Kollmorgen were designed to meet the Observa-Domes unique application and the safety standard of the USAF which can be seen in Figures 1-4.

The electrical schematics in Figures 1 and 2 detail the exteranl circuitry to control the AKD Motor ON/OFF, emergency stop switches, remote pendant, and associated relays. The electrical schematics in Figures 3 and 4 detail the exteranl circuitry for the AKD Controller and power distribution wiring.

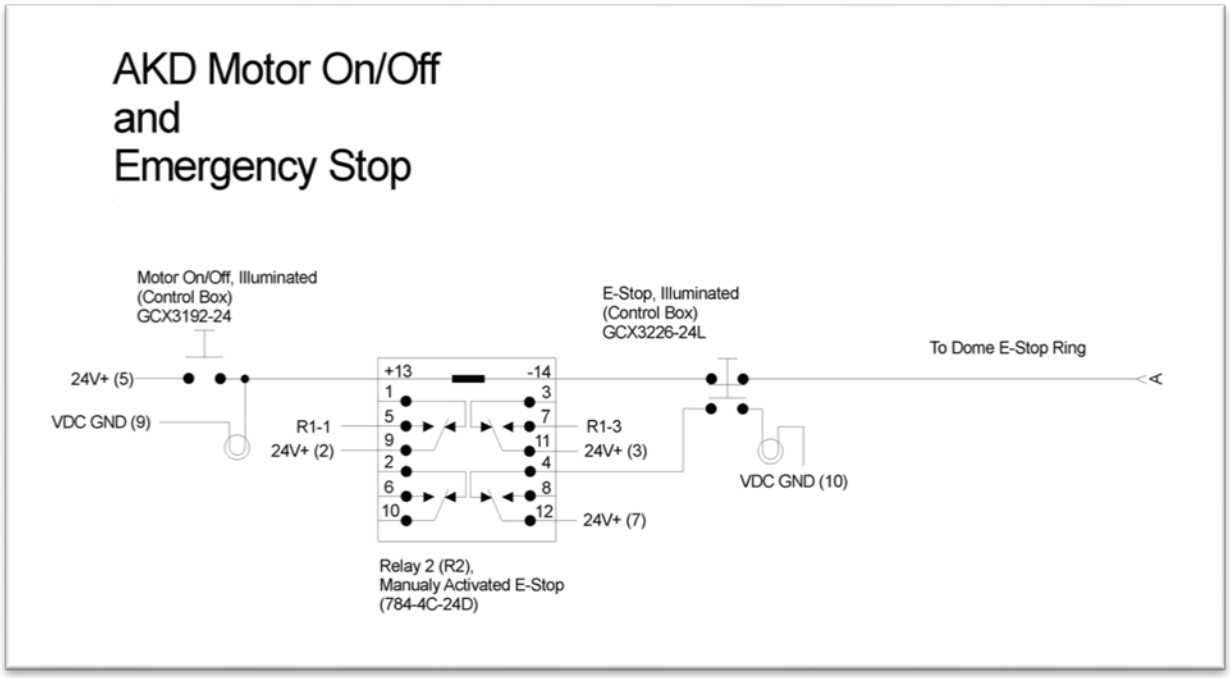

Figure 1. AKD Motor ON/OFF and emergency stop electrical schematic Part A

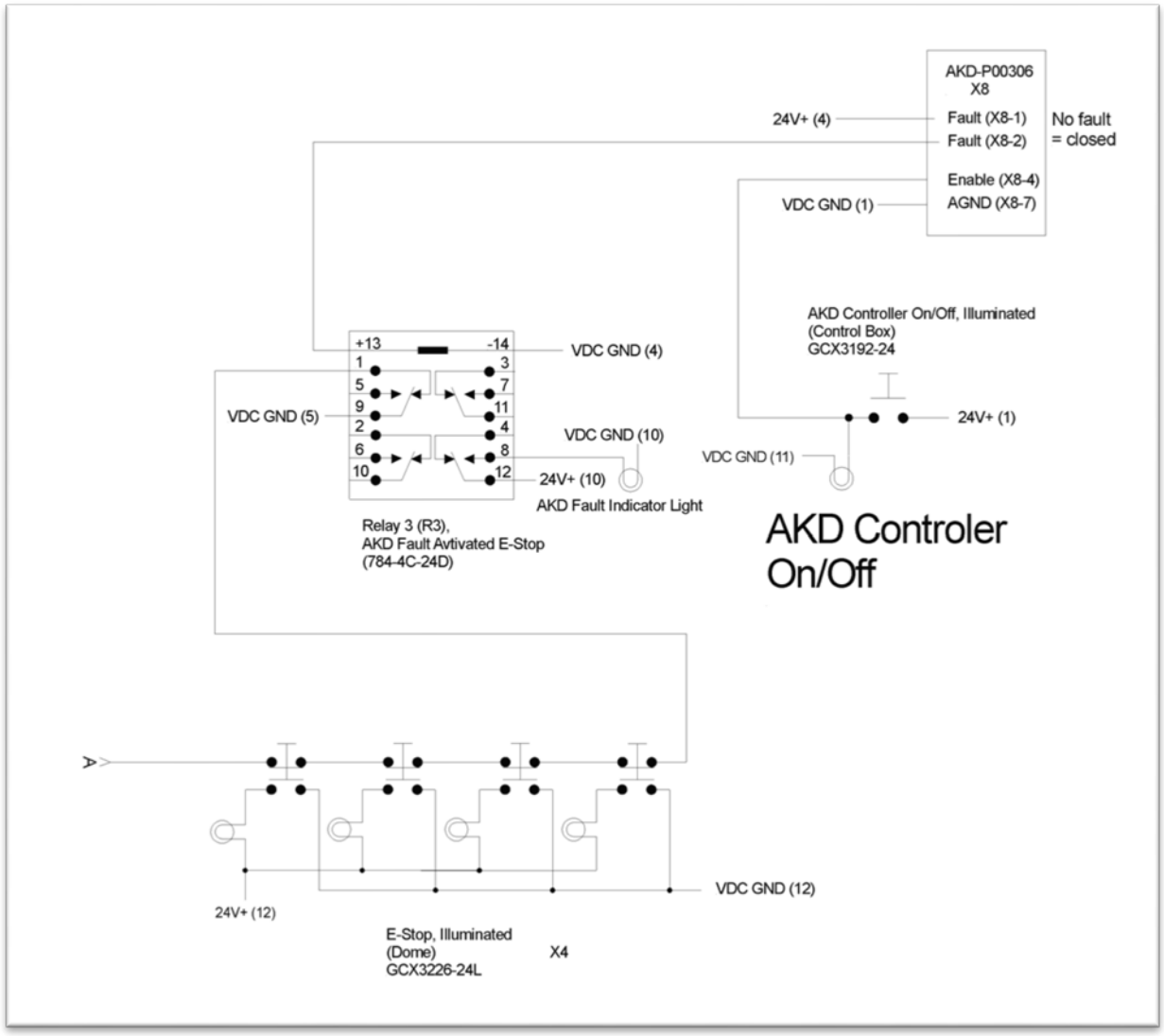

Figure 2. AKD Motor ON/OFF and emergency stop electrical schematic Part B

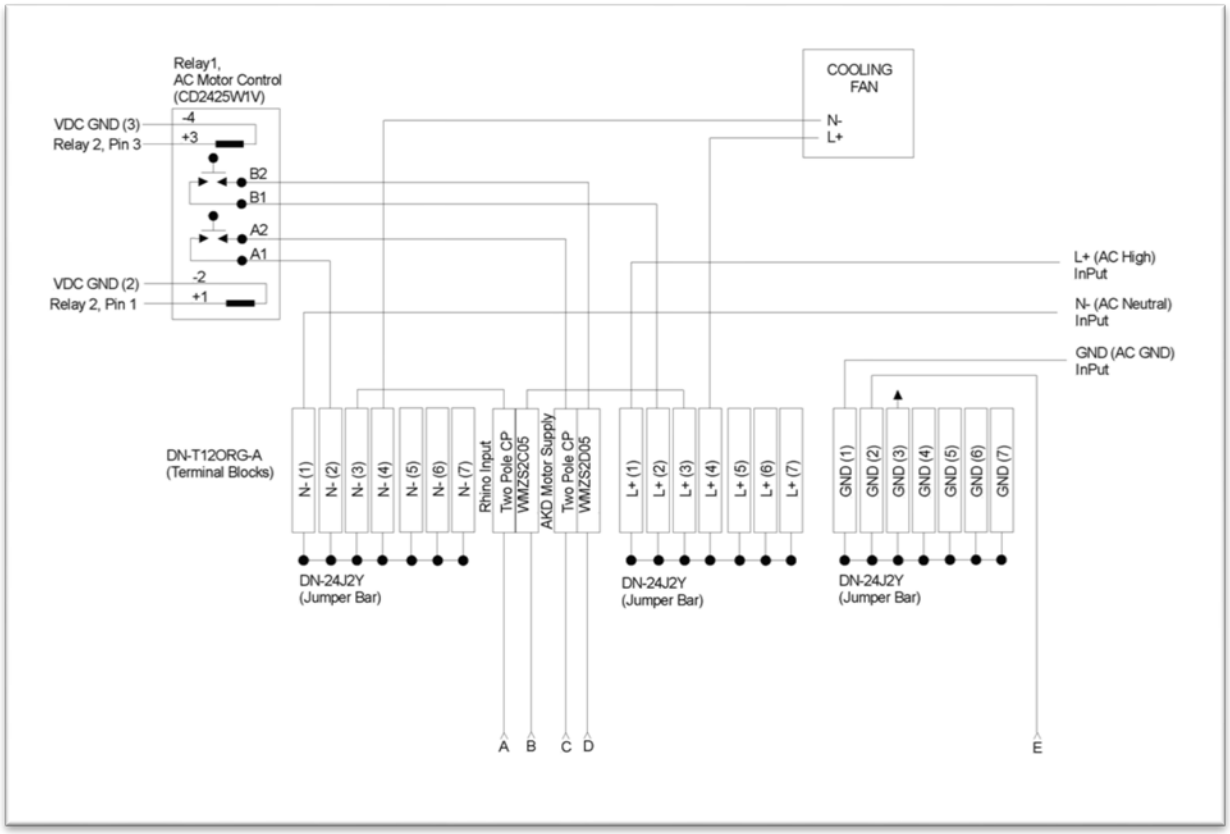

Figure 3. AKD Controller and Power Distribution Wiring schematic wiring Part A

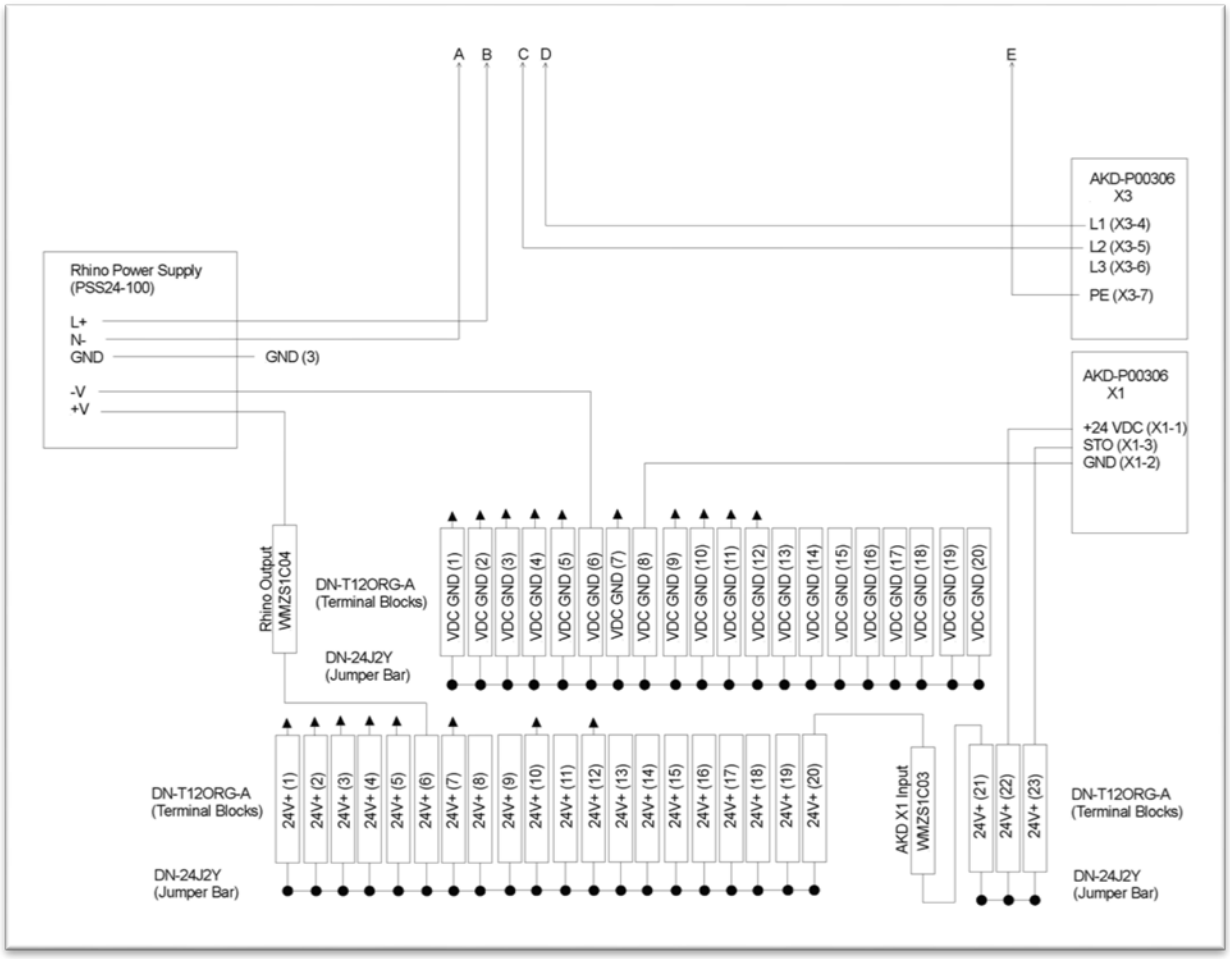

Figure 4. AKD Controller and Power Distribution Wiring schematic wiring Part B

Table 6 lists all relevant electrical schematics, created in AutoSketch 9, shown in Figures 1-4.

Table 6. Relevant electrical schematics, created in AutoSketch 9

AKD Motor and Controller ON OFF Wiring.SKF	For engineering use and modification
AKD Motor and Controller Power Distrubution.SKF	For engineering use and modification
Motor Ctrl ON_OFF_A.SKF	For Tech Report publication only
Motor Ctrl ON_OFF_B.SKF	For Tech Report publication only
Power Distribution_A.SKF	For Tech Report publication only
Power Distribution_B.SKF	For Tech Report publication only

The control box shown in Figure 5 references all requisite components necessary to build the external control circuitry. Each component has a unique designator which is cross referenced in Table 7 showing the part number, manufacturer, and a brief description.

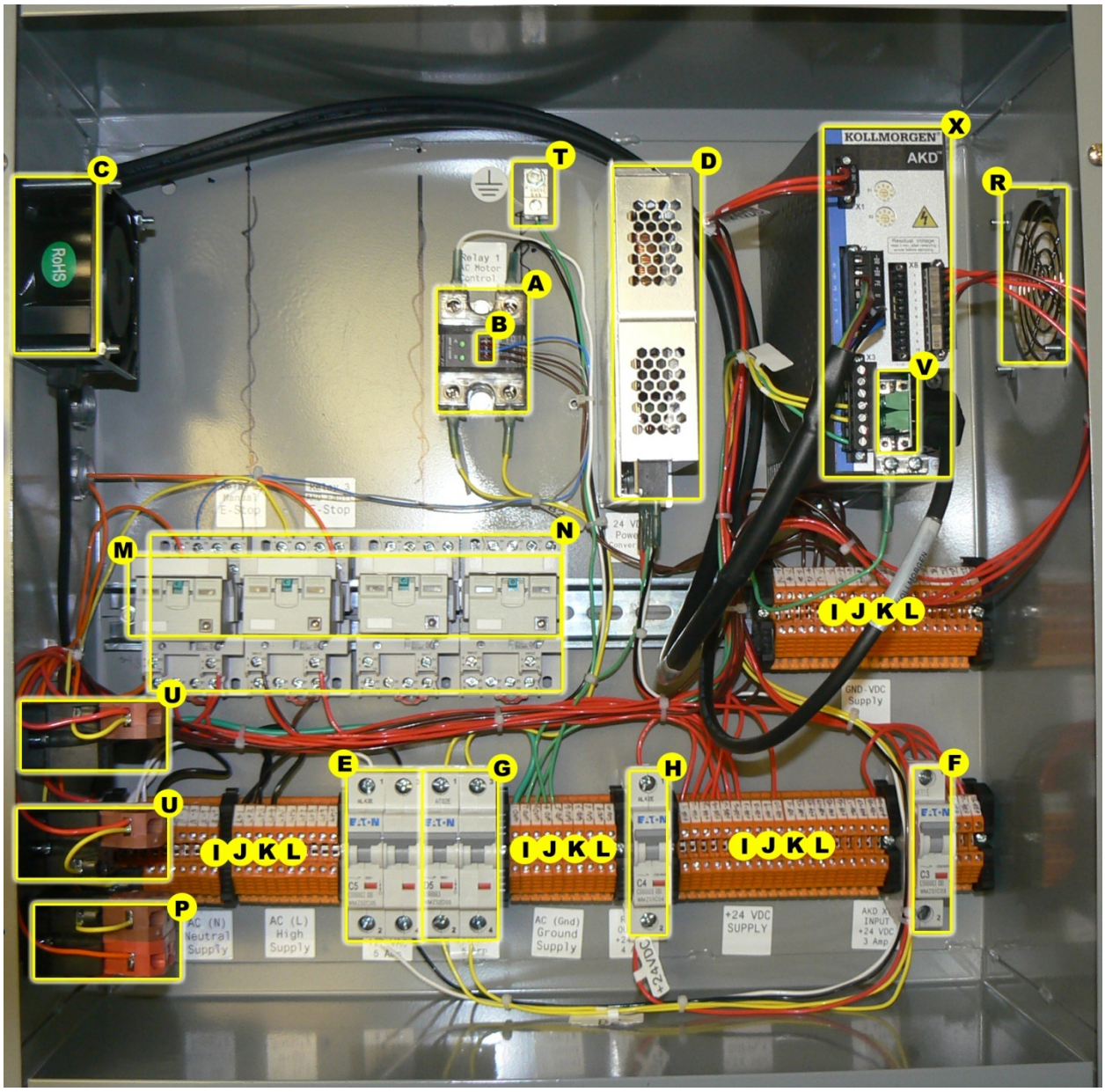

Figure 5. Control box with major components identified

Table 7. All requisite components for the control box

Designator	Part Number	Manufacturer	Description
A	CC2425W1V	Crydon	Dual I/O, solid state, panel mount relay.
B	3-640440-4	TE Connectivity	4-pin connector for solid state relay
C	MC36422	MultiComp	80mm AC cooling fan
D	PSS24-100	Rhino	24VDC (adjustable) 100watt panel mount power supply
E	WMZS2C05	Eaton	2 pole, 5Amp, C-curve breaker
F	WMZS1C03	Eaton	1 pole, 3Amp, C-curve breaker
G	WMZS2D05	Eaton	2 pole, 5Amp, D-curve breaker
H	WMZS1C04	Eaton	1 pole, 4Amp, C-curve breaker
I	DN-T12ORG-A	DINnector	DIN connector/ terminal
J	DN-R35HS1-2	DINnector	DIN panel mount rail
K	DN-EB35-A-10	DINnector	DIN end block/ stop
L	DN-24J2Y	DINnector	DIN jumper bar
M	784-4C-24D	Automation Direct	Cube relay, 24VDC coil voltage, 4PDT, 15A contact rating, with LED indicator and push-to-test button
N	784-4C-SKT-1	DINnector	DIN-rail socket for 784 series cube relays
O	HW-N4X4PB-22	Automation Direct	Non-metallic In-line series 8” x 4” x 4” enclosure for 4 standard 22mm pushbuttons
P	GCX3226-24L (Qty 5)	Automation Direct	Red pushbutton, 22mm plastic, latch with twist-to-release, LED illuminated, 24 VAC/DC, 40mm mushroom operator, 1 N.C. contact block
Q	GCX3131	Automation Direct	Pushbutton, 22mm plastic, twist-to-release, red 40mm mushroom operator, 1 N.C. contact block
R	MC32705	MultiComp	Fan blade/ finger guard
S	SC181808NK	Weigmann (Hubbell)	18 x 18 x 8 inch NEMA 1 enclosure, screw cover junction box or pull box, no knockouts, wall mount
T	WGNDKT	Weigmann (Hubbell)	Field Grounding Kit, required for CSA on RSC (NEMA 3R) and SC (NEMA 1) series enclosures
U	GCX3192-24	Automation Direct	Green pushbutton, 22mm plastic, push ON - push OFF, incandescent illuminated, 24 VAC/DC, flush operator with colored plastic ring, 1 N.O
V	DGB9FT	L-Com	DB9 female connector field termination block
W	GCX3191-24	Automation Direct	Pushbutton, 22mm plastic, push ON - push OFF, incandescent illuminated, red, 24 VAC/DC, flush operator with colored plastic ring
X	AKD-P00306-NAAN-0000	Kollmorgen	AKD controller
Y	SA100SL (Qty 4)	Weigmann (Hubbell)	Single switch enclosure for remote emergency stops

Table 8. All requisite Kollmorgen components

Controller	AKD-P00306-NAAN-0000
Servomotor	AKM31E-ACCNC-00
Gearhead	XT-080-100-0
Encoder	HC625500063DT
Motor Power Cable	VP-507BEAN-12
Motor Feedback Cable	VF-DA0474N-12

6.0 SERVOMOTOR INSTALLATION AND ADJUSTMENT PROCEDURES

Figure 6 shows the servomotor and gearhead with external mounting hardware and electrical cabling. The mounting hardware allows for three adjustments affecting how the rotational tire contacts the Observa-Dome; rotational tire level adjustment, macro depth adjustment and micro depth adjustment.

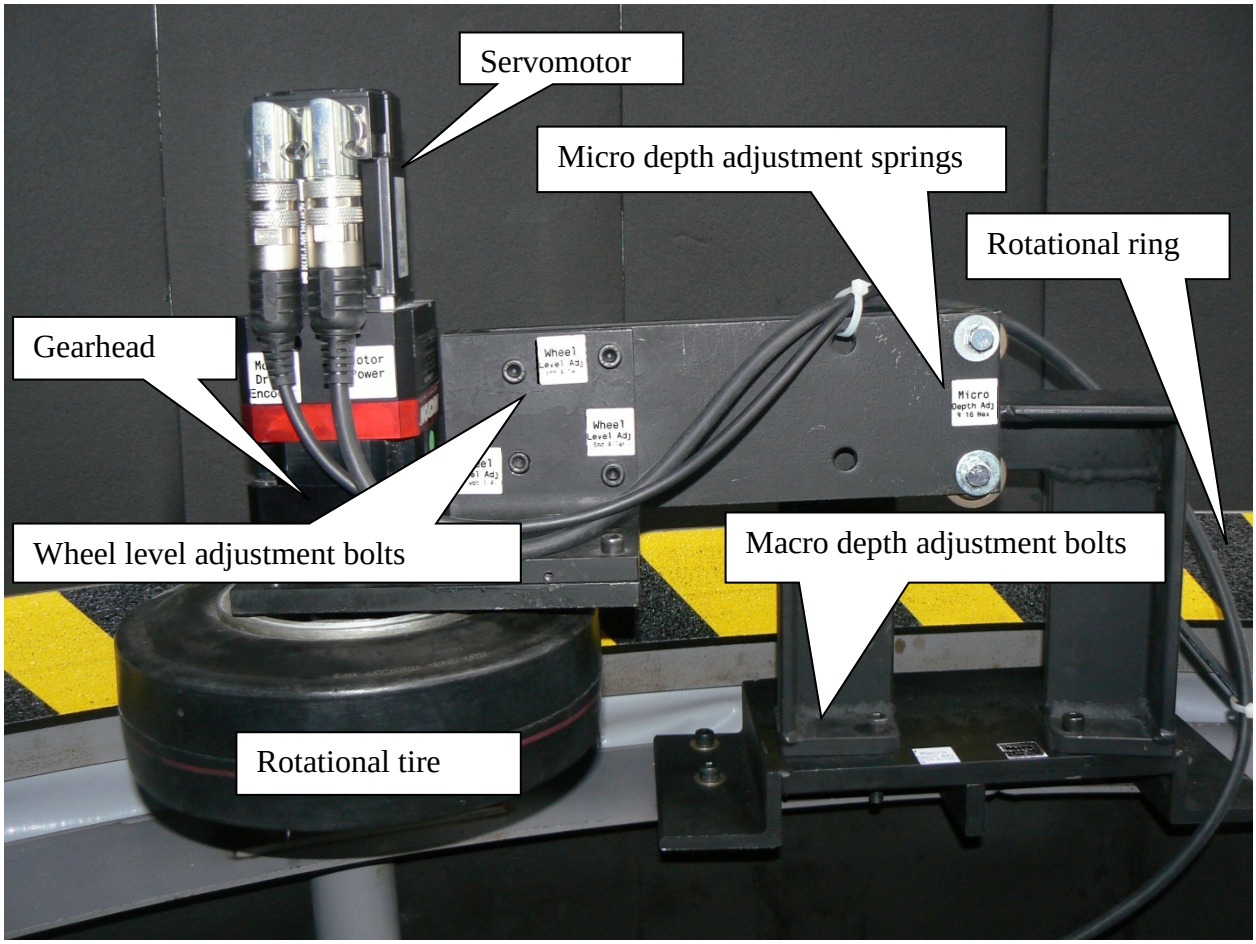

Figure 6. Servomotor and gearhead with external mounting hardware

For the Observa-Dome to rotate properly the rotational tire must be parallel to its rotational ring both shown in Figure 6 and Figure 7.

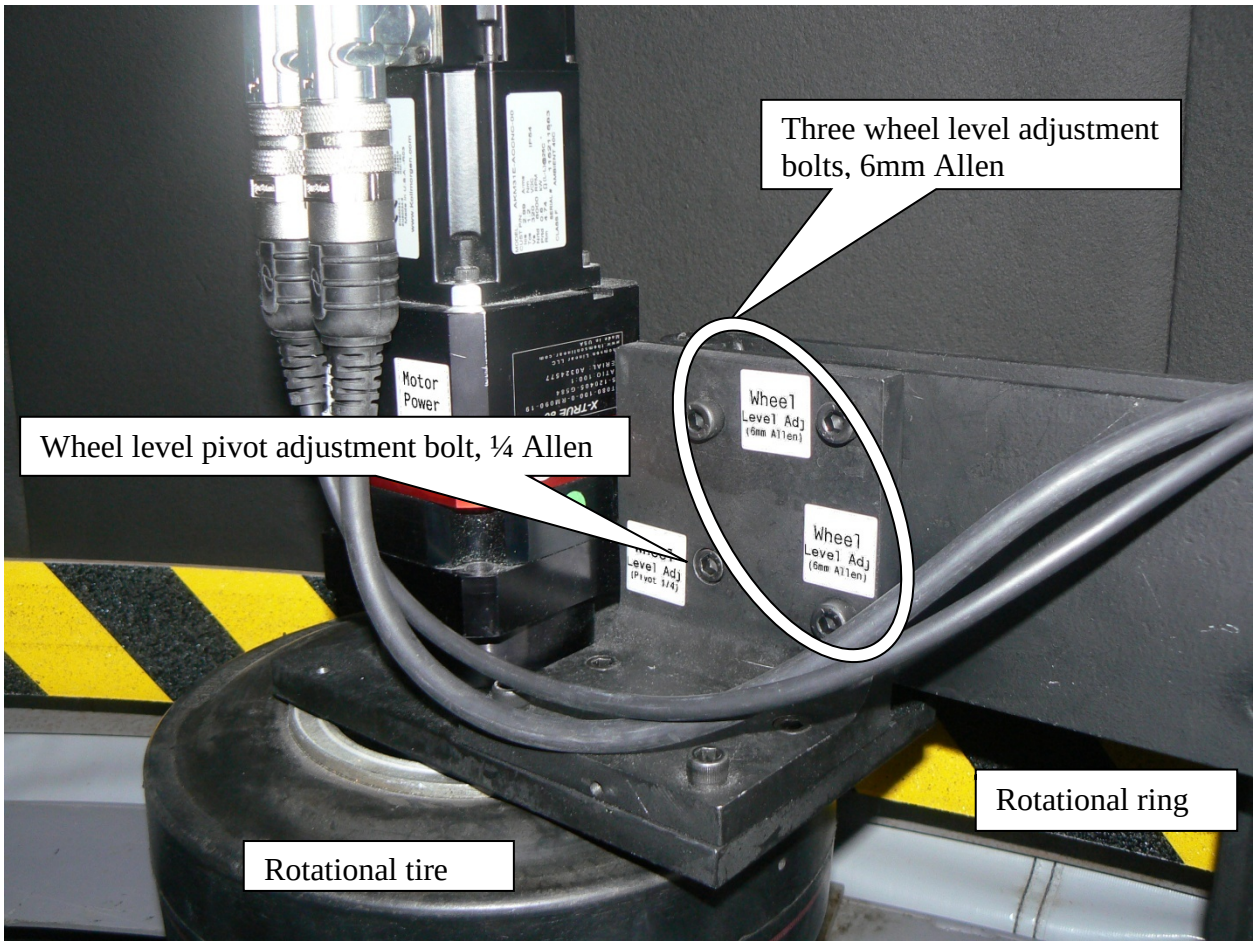

Figure 7. Rotational tire leveling adjustment hardware

To adjust the position of the rotational tire with respect to the rotational ring, loosen the wheel level pivot adjustment bolt and the three wheel level adjustment bolts shown in Figure 7. The holes drilled for the three wheel level adjustment bolts are elongated allowing the rotational tire to rotate clockwise or counter clockwise around the wheel level pivot adjustment bolt. Tighten the wheel level pivot adjustment bolt and the three wheel level adjustment bolts to approximately 16 foot-pounds after the rotational tire is parallel to the rotational ring.

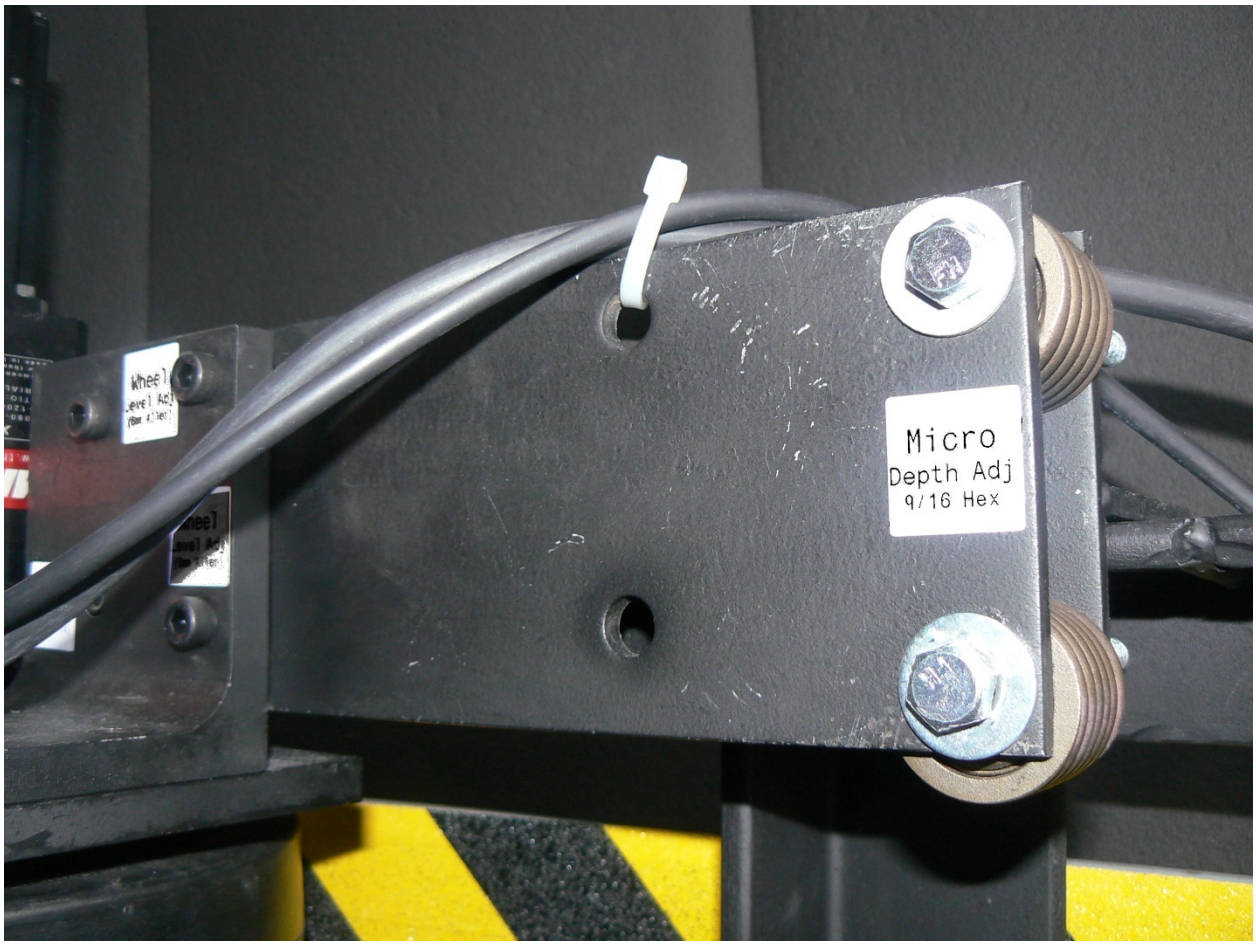

Figure 8. Micro depth adjustment springs

Depth adjustment of the rotational tire with respect to the rotational ring refers to the amount of pressure placed on the rotational ring by the rotational tire. This adjustment is broken into macro depth adjustment and micro depth adjustment shown in Figure 6. To initially adjust the macro depth or to remove the rotational tire for service the micro depth adjustment springs must be fully collapsed as shown in Figure 8.

IMPORTANT: Rotational tire must be deflated prior to making macro depth adjustment.

Macro depth adjustment is necessary to ensure appropriate pressure between the rotational tire and the rotational ring. To perform macro adjustment, deflate the rotational tire. With the micro depth adjustment springs fully collapsed loosen the macro depth adjustment pivot bolts and the macro depth adjustment anchor bolts. Because the hole for the macro depth adjustment anchor bolt is elongated the rotational tire can rotate clockwise or counter clockwise around the pivot bolt as shown in Figure 9. A clockwise rotation moves the rotational tire closer to the rotational

ring. With the bolts loosened, press the rotational tire against the rotational ring ensuring firm contact between the two surfaces. Tighten all the macro adjustment bolts to approximately 16 foot-pounds and inflate the rotational tire to 50 PSI.

Final depth adjustment is made with the micro depth adjusting springs shown in Figure 8. Using two 9/16 wrenches loosen the bolts approximately four or five full turns to expand the depth adjustment springs. If the rotational tire slips on the rotational ring during use, expand the depth adjustment springs a few more turns. Expanding the springs completely may put excessive side load on the gearhead resulting in premature failure.

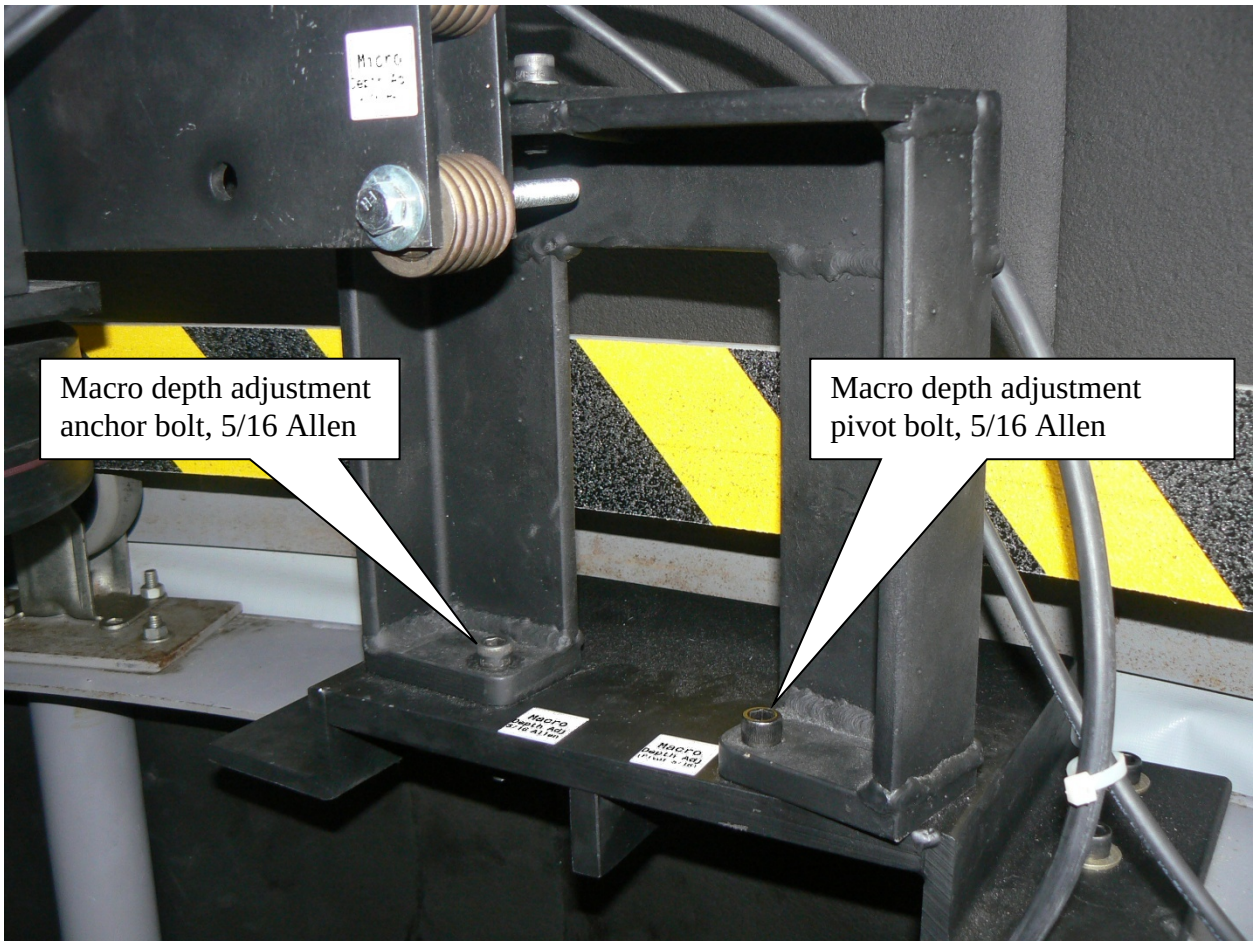

Figure 9. Macro depth adjustment bolts

7.0 ENCODER INSTALLATION AND ADJUSTMENT PROCEDURES

The Series HC25 Danaher Encoder (HC625500063DT) is connected the AKD Controller (AKD-P00306-NAAN-0000) connector X9 via Field Installable DB9 connector shown in Figure 10.

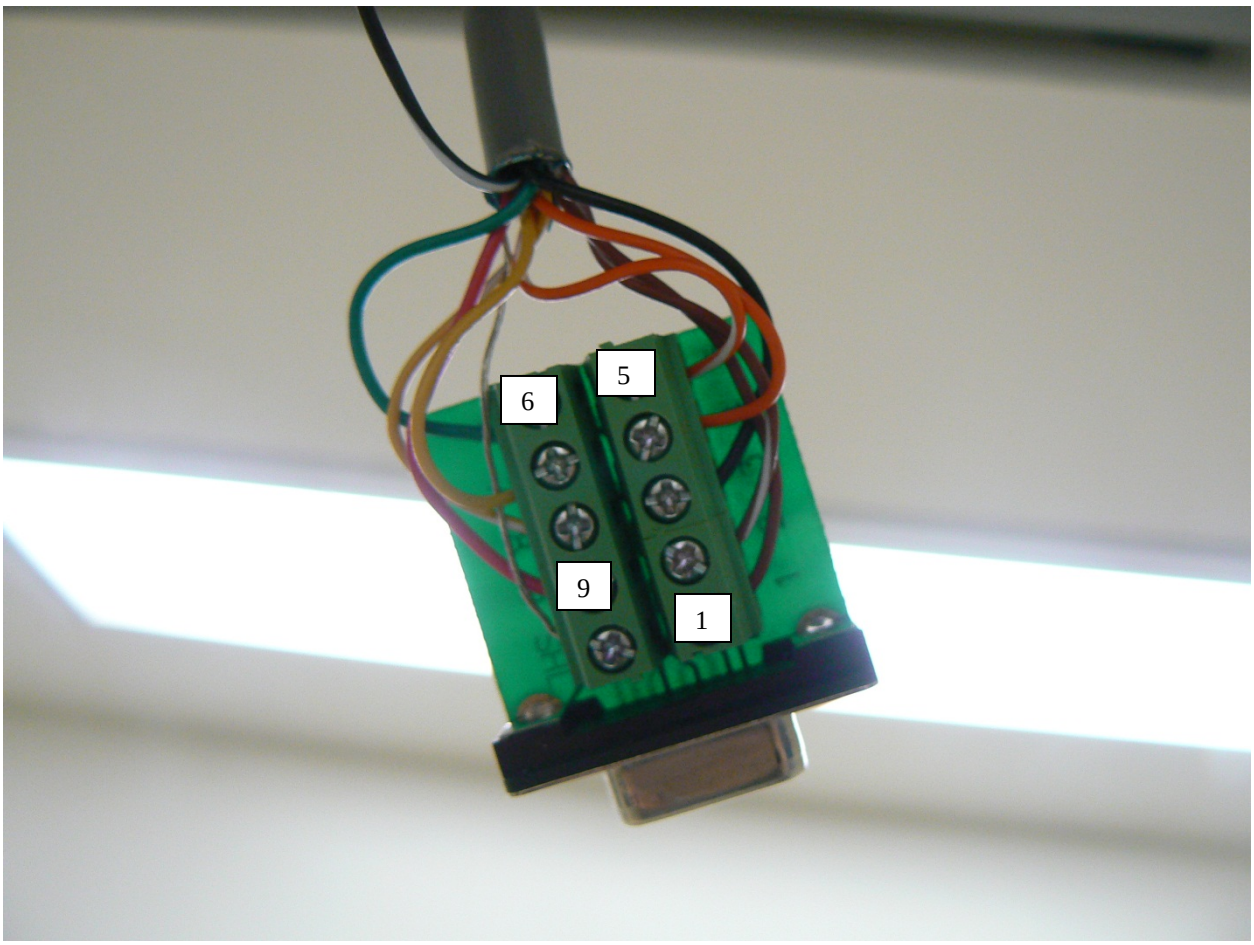

Figure 10. HC625500063DT encoder connected to the Field Installable DB9 connector

The encoder signal wires are connected to the field installable DB9 connector as shown in Table 9.

Table 9. HC625500063DT encoder connected to the Field Installable DB9 connector

AKD Connector X9	Encoder Signal	Wire Color
1	A+	Brown
2	A-	Brown/White
3	GND	Black
4	B+	Orange
5	B-	Orange/White
6	SHIELD	Green
7	Z+	Yellow
8	Z-	Yellow/White
9	+5V Encoder Supply	Red
10	SHIELD	Bare

Referring to Figure 11, the Series HC25 Encoder should be adjusted so the encoder wheel rides near the center of the rotational ring using the two height adjusting rings with a 3/16 Allen wrench. The lower height adjusting ring sets the height of the encoder wheel as well as the force of the tension spring ensuring the encoder wheel firmly contacts the rotational ring. The lower height adjusting ring should the rotated clockwise to increase spring tension. After the encoder wheel's height and tension spring are adjusted, the upper height adjusting ring can be secured with a 3/16 Allen wrench.

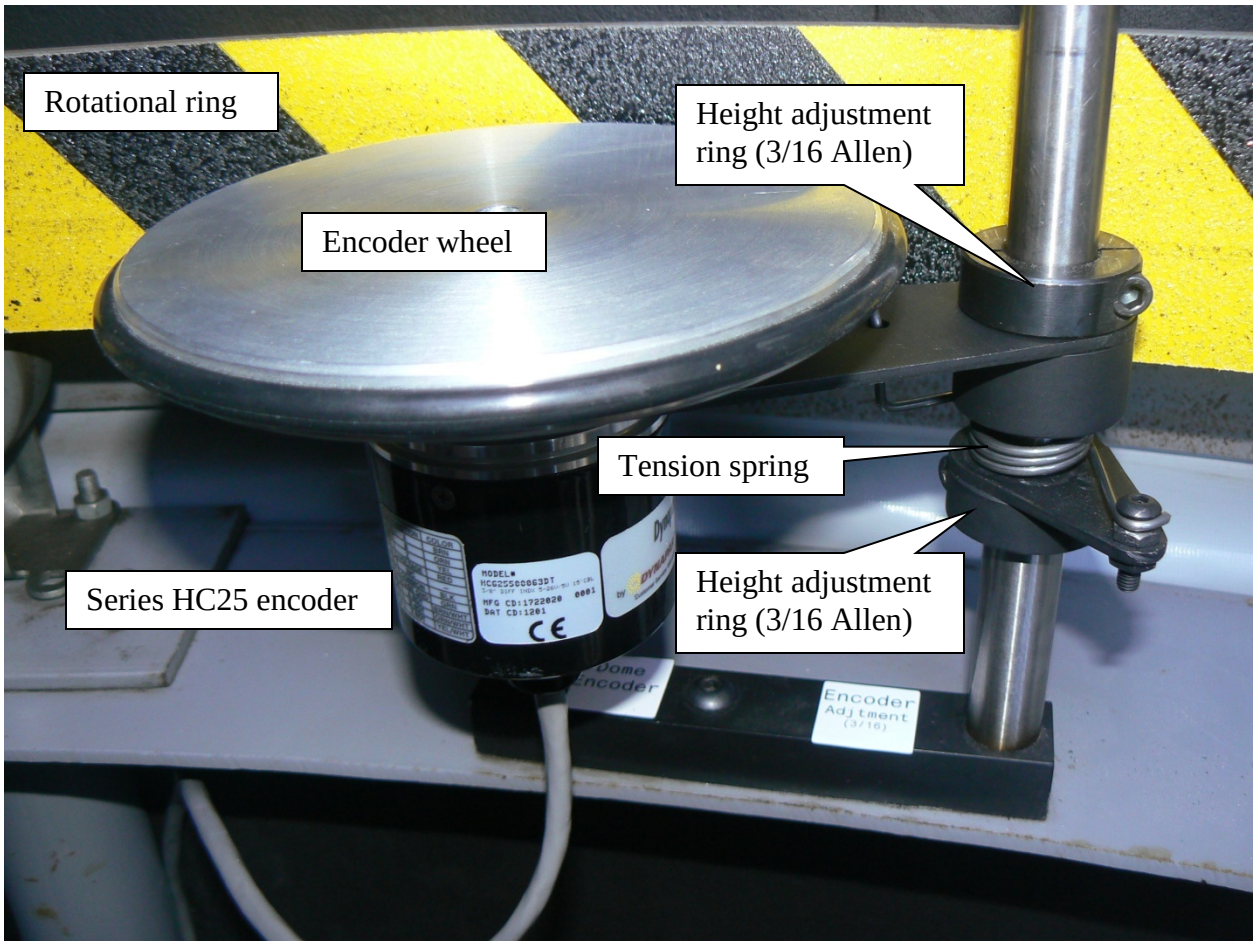

Figure 11. Height and depth adjustments for the Series HC25 Encoder

8.0 POWER UP, POWER DOWN, AND EMERGENCY STOP PROCEDURES.

The automated rotation control system power up porcedure begins with confirming the control box ON/OFF switch is in the OFF position as shown in Figure 12. The remainder of the power up procedure described below references Figure 12:

a) Remove the administrative lock from the general duty safety switch box labeled Scope Power, shown in Figure 13, and move the disconnect lever to the ON position.
b) Move the control box ON/OFF switch to the ON position, the switch should illuminate RED when power is supplied to the enclosure.
c) Press the AKD Controller ON/OFF switch, the switch should illuminate GREEN when power is supplied to the AKD Controller.

d) Wait approximately 30 seconds for the AKD Controller to go through its initialization procedure.
    a. The AKD Controller is now ready for Ethernet communications.
    b. Continue to the next step if it's desired to rotate the Observa-Dome.
e) Press the motor ON/OFF switch, the switch should illuminate GREEN when power is supplied to the rotational motor.
    a. The rotational motor is now energized and waiting for commands from the AKD Controller.

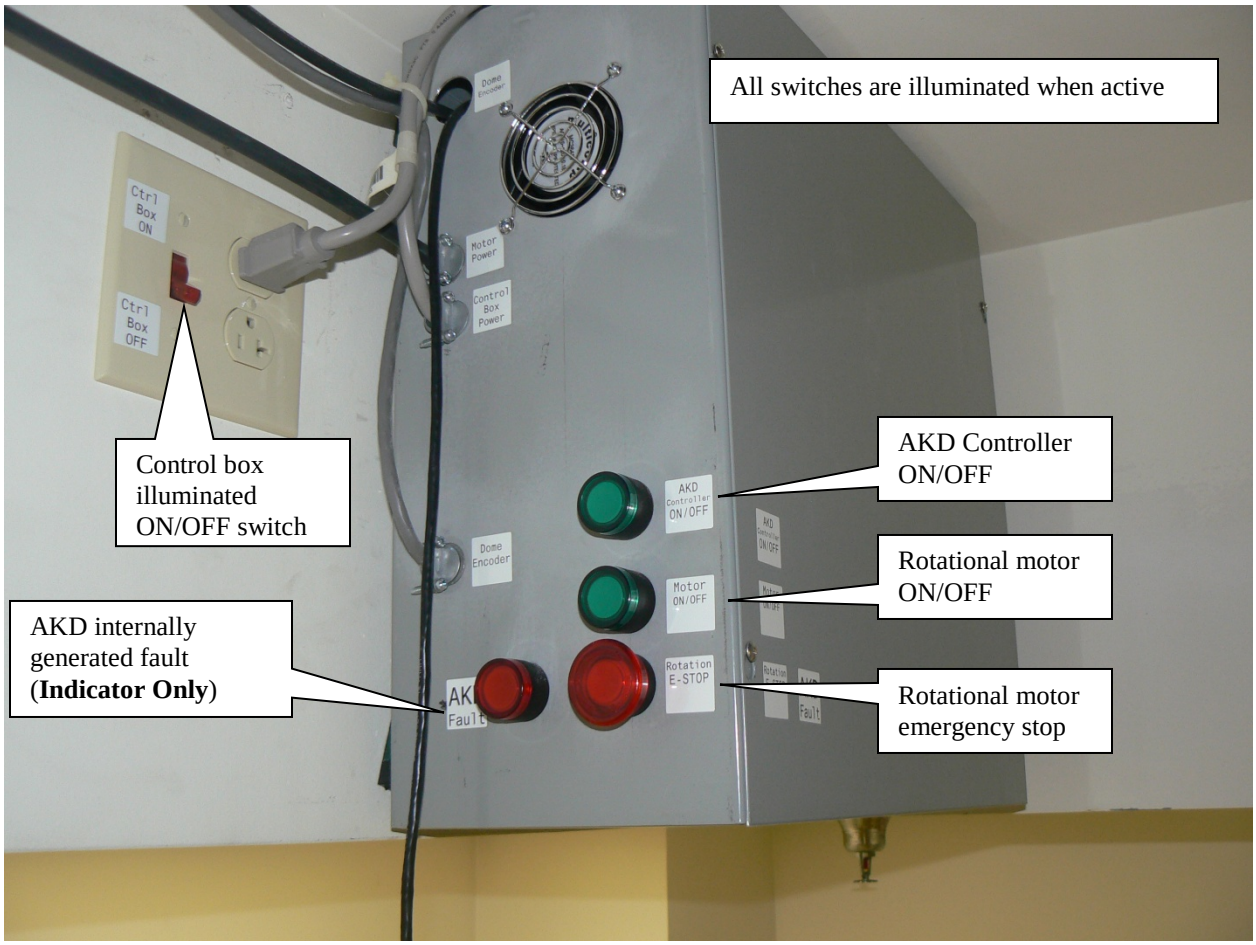

Figure 12. Automated Rotation Control System Enclosure

If the AKD Controller generates and internal fault signal the AKD Fault indicator light, shown in Figure 12, will illuminate RED and disconnect power from the rotational motor. The AKD Controller remains powered so that any internal codes can be retrieved for diagnostic purposes. When the fault is repaired the fault signal will clear and the light will extinguish.

The rotational motor can be manually stopped by pressing the rotational E-STOP switch shown in Figure 12. The switch will illuminate RED and disconnect power from the rotational motor leaving the AKD Controller powered. To reverse the rotational E-STOP operation, press and twist the switch counterclockwise, the switch will no longer be illuminated.

Figure 13. General Duty Safety Switch with Administrative Lock

In addition to the rotational E-STOP located on the Automated Rotation Control System Enclosure, there are several additional rotational E-STOP switches inside the Observa-Dome near the rotational motor, which operate identically.

The power down procedure is:

a) Press the Motor ON/OFF switch, it should no longer be illuminated.
b) Press and twist the rotational E-STOP switch counterclockwise if it was used.
c) Press the AKD Controller ON/OFF switch, it should no longer be illuminated.
d) Move the Control Box ON/OFF Switch to the OFF position, the switch should no longer be illuminated.
e) Move the disconnect lever of General Duty Safety Switch box labeled Scope Power to the OFF position and reinstall the administrative lock.

9.0 CONCLUSION

This document highlights the major hardware components of the automated dome control system, and outlines the procedure necessary for calibrating the system for operational use with the RHCV telescope. The automated system is intended to be used as an integrated part of the RHCV observatory system.

The software configuration and operations guide is included in the software system document.